Hit Reconstruction & Purity

Matt Thiesse

31 August 2016

35-ton Sim/Reco Meeting

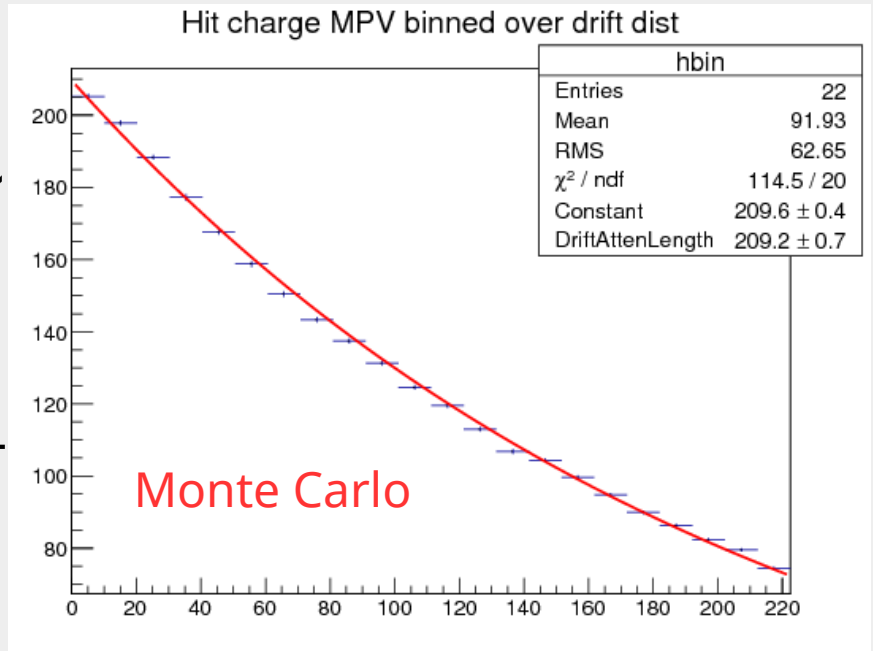
Purity Study Using TPC Data

- Complementary to dedicated Purity Monitors
- Charge attenuation due to electron attachment to electronegative impurities:

$$Q_{\text{collected}} = Q_{\text{ionized}} e^{-t_{\text{drift}}/\tau_{\text{life}}}$$

- Impurity concentration is determined from electron lifetime:

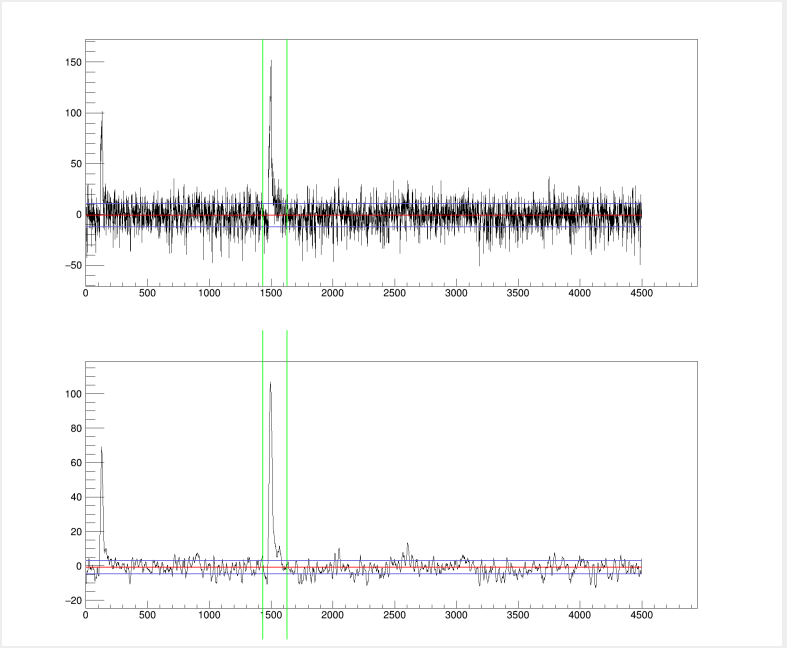
$$\tau_{\text{life}} = \left(\sum_i k_i n_i\right)^{-1}$$

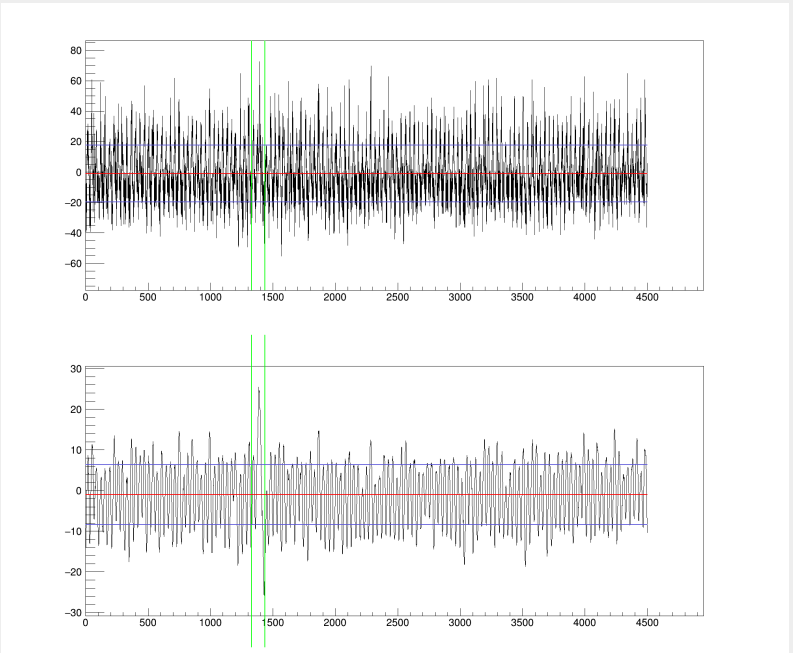


- 2 important measurements:
  - *Electron lifetime:*
    - *At different times*
    - *In different regions of the detector*
- Data quality issues mean only collection plane information is useful!

Previously

- Wrote new Hit Finder which accounts for between-channel variations in noise
- Improved hit/noise separation algorithm
  - Previously described as a “Track-finder”, but now I’m hesitant to use that term because of its extremely limited scope
- Purity analysis code is ready, just need to feed it sensible reconstructed hits
- Need to validate the hit finding algorithm…



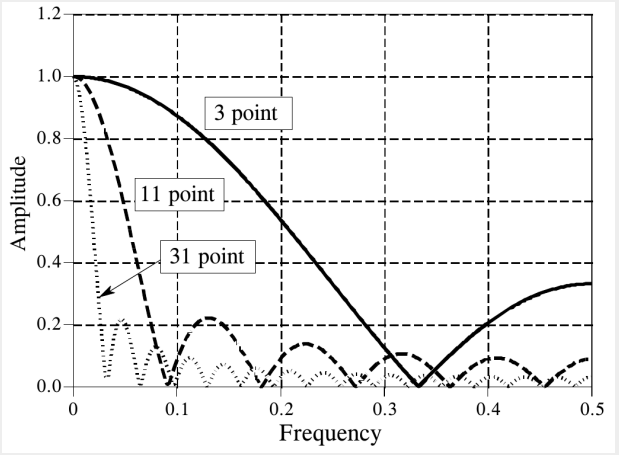


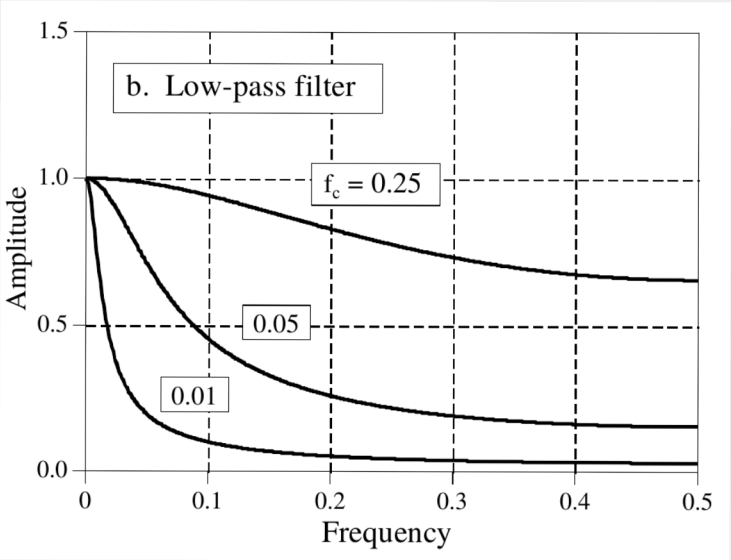
“Tracker” improvements

- Restructure code package
  - More generalizable and segmented
- Use MLE for “track” fitting (http://dx.doi.org/10.1006/cviu.1999.0832), rather than χ^2/DOF or Sum of squared residuals / DOF
  - Significantly improved fit process, more robust
  - Minimise the -Log(likelihood)
  - Points nearer to best fit line are more heavily weighted
  - More inliers → better fit
- Fit to a 2-dim polynomial, to account for *slight* bending of the tracks from scattering
- Use seeded RNG from LarSoft for deterministic random sampling
- Fixed incorrect “track pitch” calculation: assume θyx and θyz from counter positions

Hit Finder Improvements

- Previously used simple moving average filter
  - Frequency response function for this filter type is very poor, not optimal
- Use single-pole recursive filter to preserve a smooth frequency response





$$y[n] = a_0 x[n] + a_1 x[n-1] + a_2 x[n-2] + a_3 x[n-3] + \cdots$$
$$+ b_1 y[n-1] + b_2 y[n-2] + b_3 y[n-3] + \cdots$$

EQUATION 19-1
The recursion equation. In this equation, $x[\ ]$ is the input signal, $y[\ ]$ is the output signal, and the a's and b's are coefficients.

Hit Finder Improvements

- Do the filter bidirectionally, to preserve the phase of the signal (no net shift of hits in time)
- Reminder:
  - The purpose of my filtering is to allow for better hit finding and to use lower thresholds
  - On the filtered signal, I use a multiple of the signal RMS as the threshold and to find the hit endpoints
  - Hit charge is still calculated from the raw, unfiltered signal

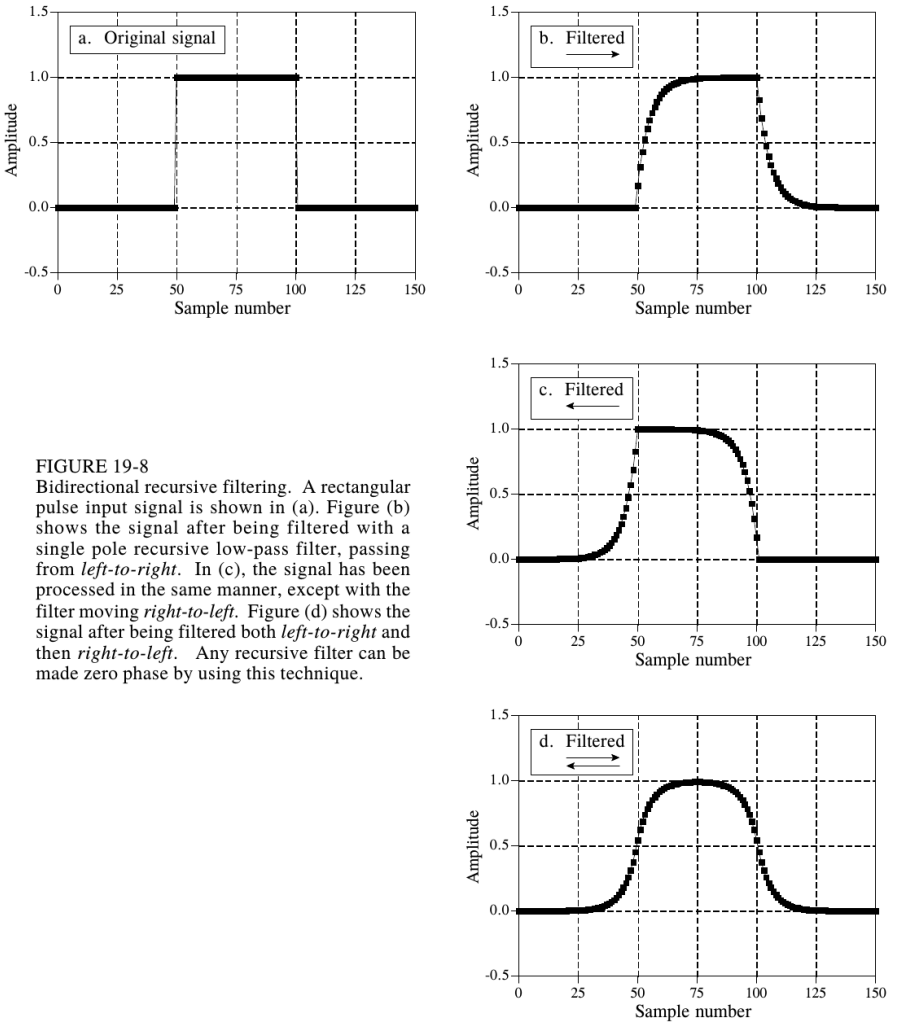


FIGURE 19-8
Bidirectional recursive filtering. A rectangular pulse input signal is shown in (a). Figure (b) shows the signal after being filtered with a single pole recursive low-pass filter, passing from *left-to-right*. In (c), the signal has been processed in the same manner, except with the filter moving *right-to-left*. Figure (d) shows the signal after being filtered both *left-to-right* and then *right-to-left*. Any recursive filter can be made zero phase by using this technique.

Hit Finder Validation

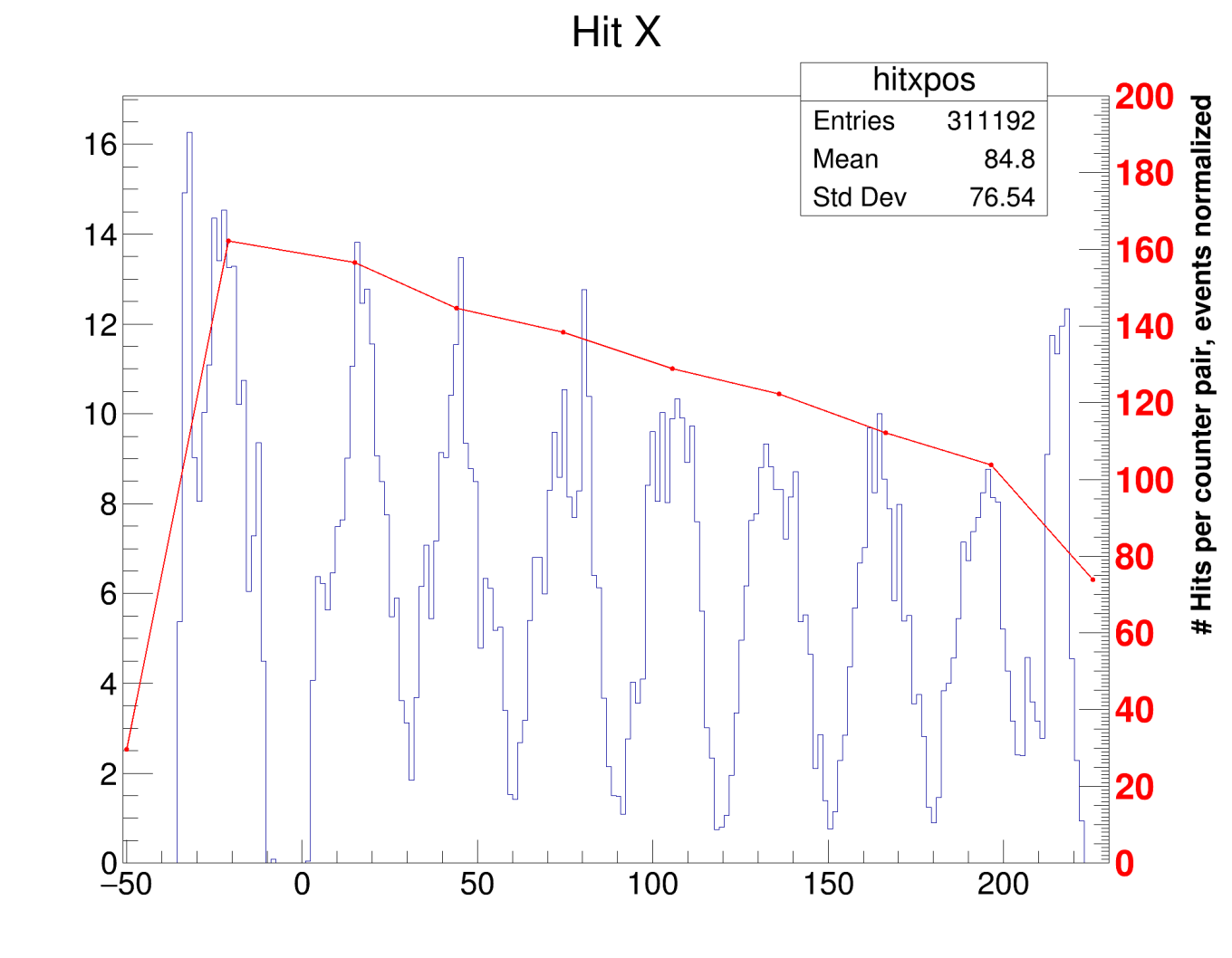
- Michelle's proposal:
  - Show that the charge distribution is not changed by using a different "threshold" for each wire
  - Want the threshold to be low enough to find even the smallest hits at the longest drift times, otherwise the landau MPV will be skewed
  - Do this on a wire-by-wire basis

1) Select opposite EW counter triggers, hits should have the smallest possible charge on each wire
2) Count number of hits vs. drift time on each wire
3) Show that this distribution is flat
4) If the hit finding threshold is above the rise of the landau, the distribution in 3) will slope down as charge is attenuated over the drift

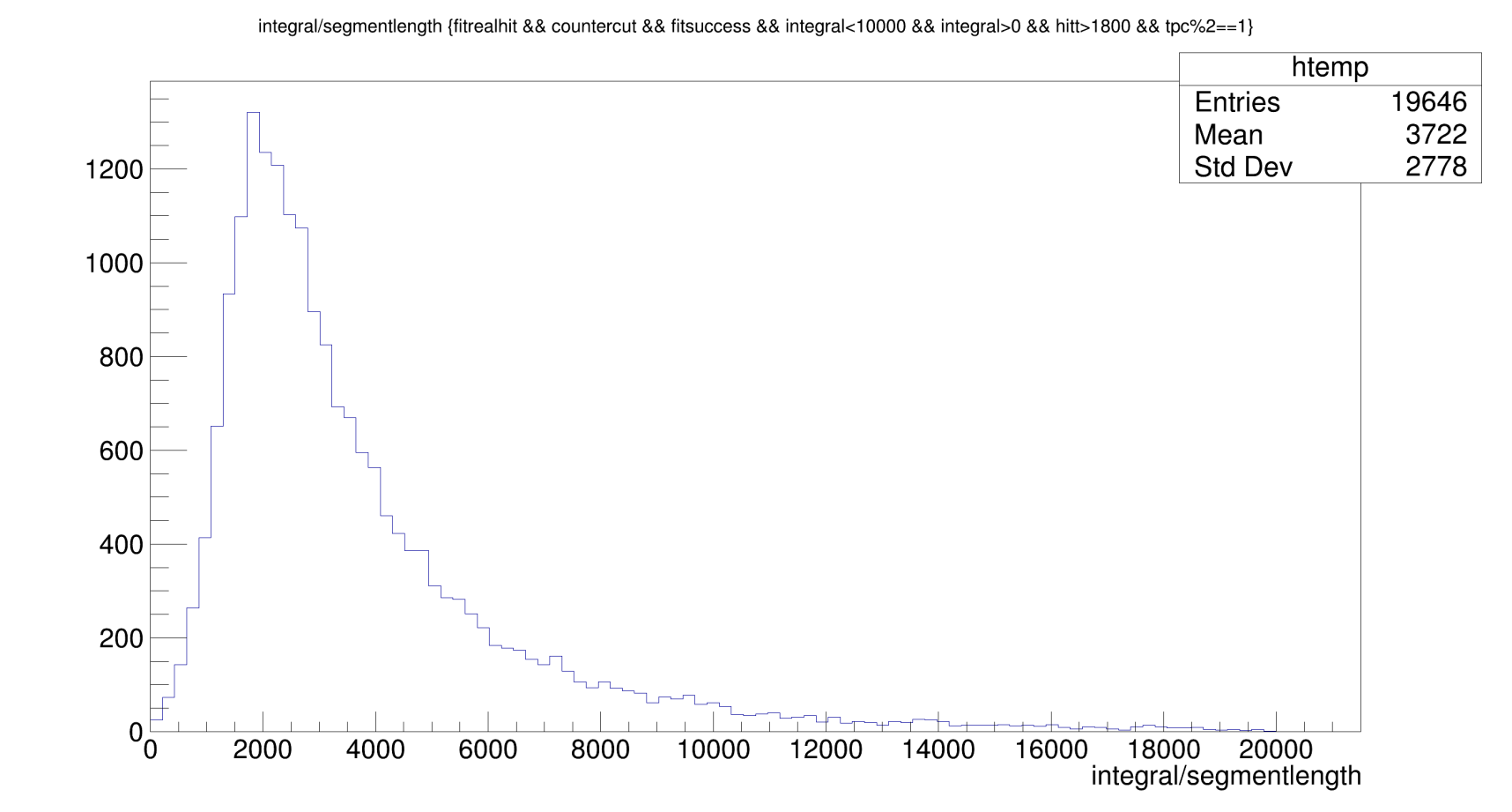
- Any other suggestions of validations are welcome!
- Need to show:
  - Noise is effectively separated from real hits
  - Charge distribution of hits is landau

Hit Finder Validation

- First pass: unsuccessful validation(???)
- Don’t know what this plot should look like for a “valid” hit finder, so can’t interpret the graph yet
- Doesn’t look good so far…

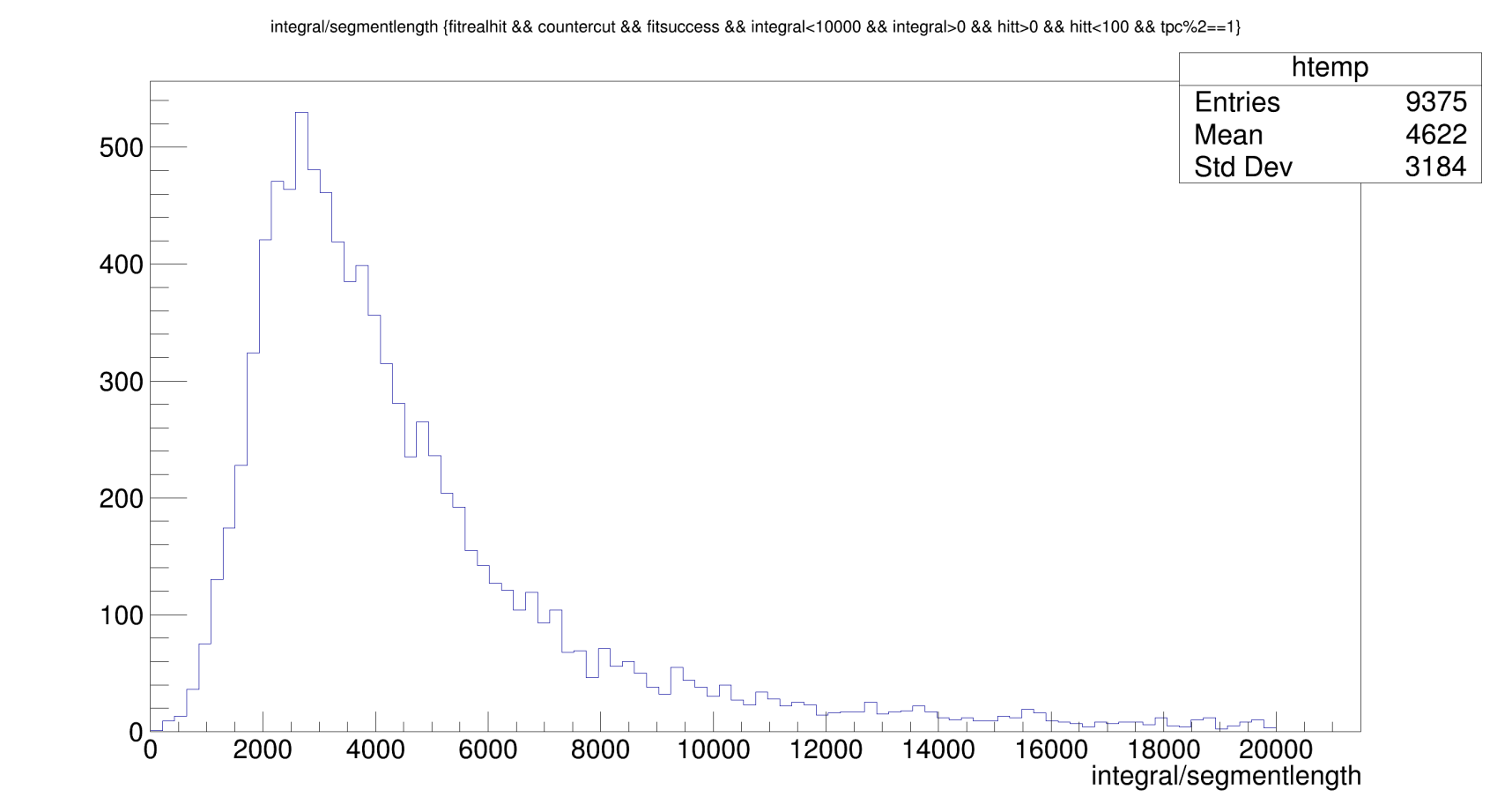


Landau-ness of Hit Charge



Long drift time, Hit integral / effective track length

Landau-ness of Hit Charge



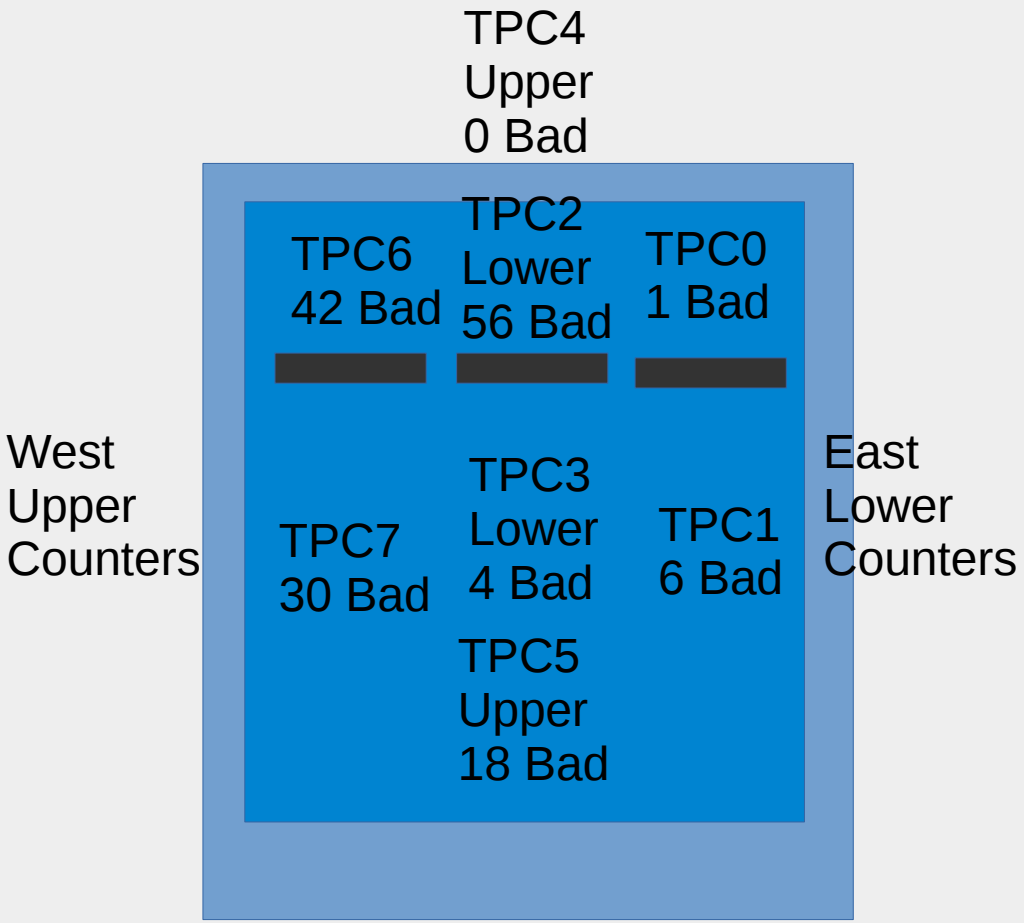
Short drift time, Hit integral / effective track length

MC Simulation verification

- In process of doing a MC study of the hit finder, would like to do another plot like on slide 8
- Jobs still running…
- (Should MC production be zero suppressed? Since data isn’t…)

Thoughts about efficiency

- For East/West muons, we expect to find a hit on every wire
- Excluding bad wires (from channelstatus_dune.fcl)
  - Obviously not a complete list
- In long drift, number of bad wires crossed, 47 +- 11 (depending on how many wires crossed in APA3vs5)
- Should find 289 +- 11 hits for EW muon in long drift and 265 +- 28 hits for EW muons in short drift
- (Some entire TPCs were off completely during some runs, some RCEs were off, but event builder still read zeros?)



Final thoughts

- The “validity” of this hit finder is still under question
- Loads more work to be done
  - Tweak algorithm parameters to make it more sensitive to lower SNR
  - Reduce the influence of “fake” noise hits even further. It’s possible, these are dominating the low end of the landau spectrum on previous plots.
  - Continue validating
    - Need to simulate to determine the expected shape of hit distribution with too-high threshold?
    - Any other ideas?
    - Repeat channel-by-channel
  - Do the purity measurement!!
    - Not possible yet because the threshold is still too high…